AutoLog Array Crane:

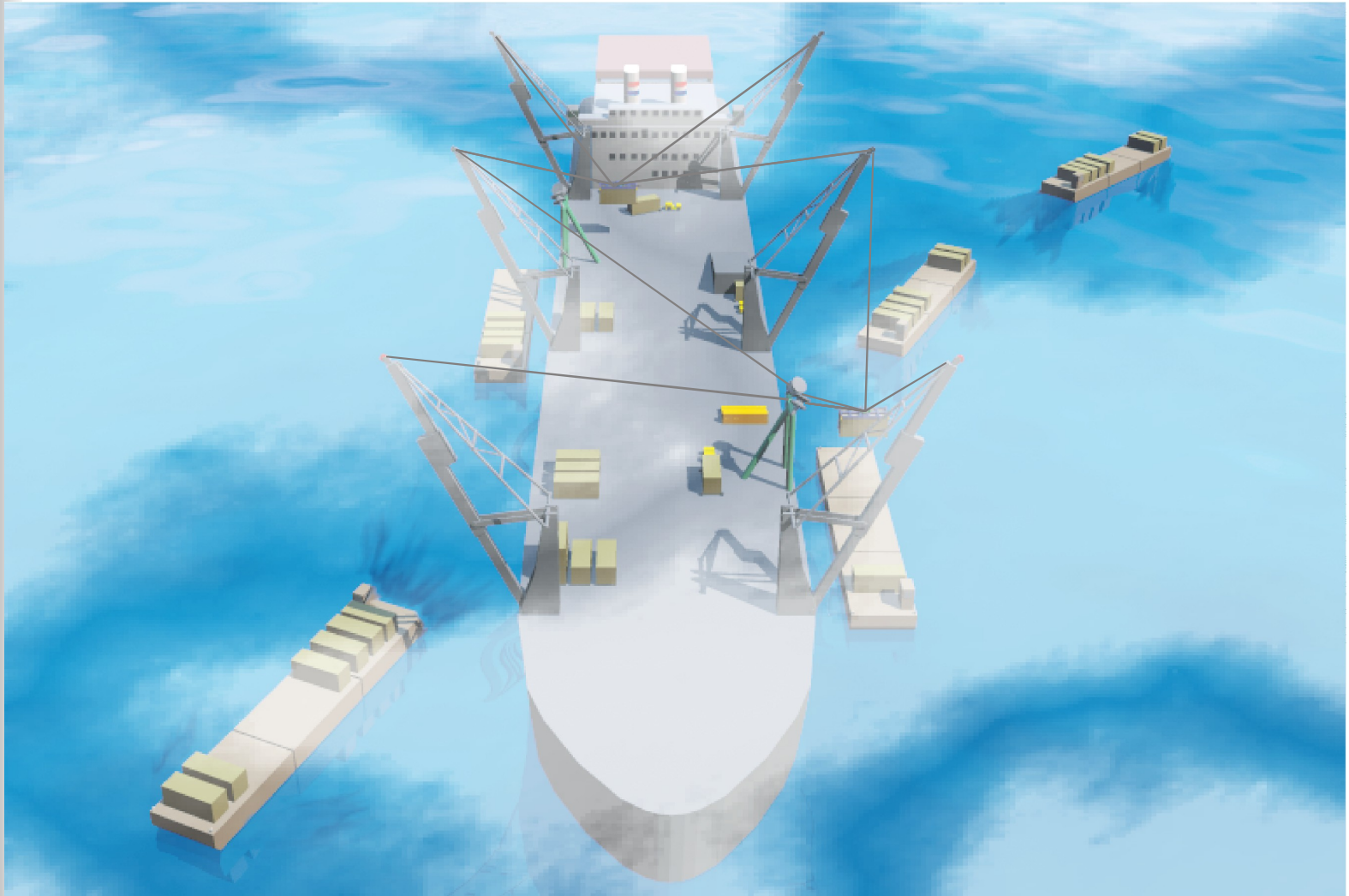* Stability Concept For Automated Logistics (AutoLog)

* 1/16th Scale Model

* Initial Demo at Sea

Penn State/Seicor/Navy

AutoLog Provides Offloading Stability At Sea

Autolog Port-At-Sea: Strategic Offloading

- **Allows Immediate Offloading on Arrival:**
  Globally;
  In Daytime, or at Night;
  In Sea State 3 or Greater;
  At Rapid Cargo Throughput Rates.
- **Turns Container Ships into Ports at Sea.**
- **Provides Low Exposure (No Port Terror).**
- **Creates Offload Options In Higher Seas.**
- **Raises Demand for Existing as well as Future Offloading Ships.**

1/16th Scale PSU AutoLog Model

[Show Videotape of 1/16th Scale AutoLog System Offloading Model Containers in Penn State High Bay Facility]

AutoLog Model at Penn State

- **Completed Scale Up to 1/16th Model from 1/32nd Scale Bench Models**

  - **Kinematics**
  - **Dynamics**
  - **Control**
  - **Mechanism Design**

- **(Facilitated by Having High Bay, Lab and Outdoor Site become Available)**
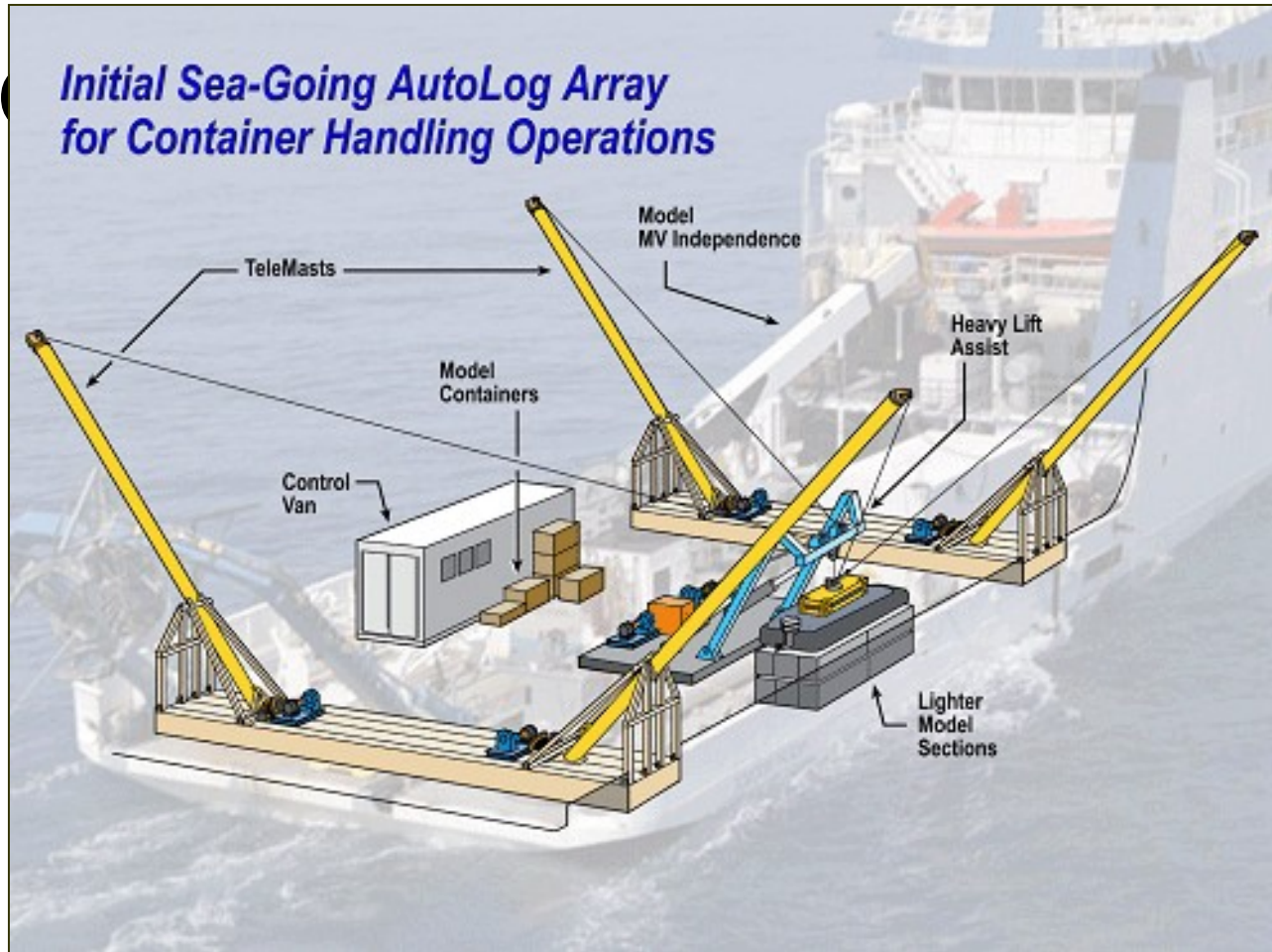
¼ Scale Ship For Initial AutoLog Demo At Sea

The MV Independence operates from Port Hueneme, CA, where the Navy's NFESC Command is located. (Planned system is drawn in red w/ lighters superimposed.)

Sea Based Logistics

Initial At-Sea

Initial Sea-Going AutoLog Array for Container Handling Operations

AutoLog System will be placed aboard the NFESC vessel MV Independence for testing higher sea state conditions.

Sea Based Logistics: AutoLog Land Test Site at

- **Initial hardware under construction.**
- **Will allow Offload operations at sea in high sea states using robotics.**

Sea Based Logistics: High Sea State Technologies (HISEA) Test Site

INV Independence

Port Hueneme Harbor

Laydown Yard

High Sea State Ocean

Amphibious Landing Beach

Site at Port Hueneme to support test and evaluation of high sea state prototypes

09/09/1   Penn State / Sei   0
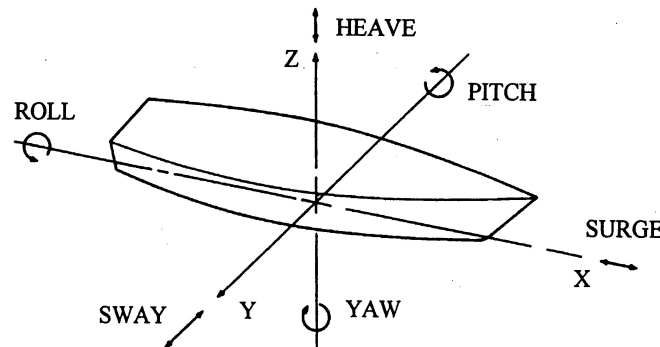
One Ideal Ship Type for Full AutoLog Proof of Concept

Skin-To-Skin Transfer Criteria

- **Avoid Problems with 6 DOF Effects (i.e. from Roll Pitch Yaw Heave Surge Sway)**

- **Minimize & Distribute Loads/Moments**
- **Maximize Reach & Workspace Area For a Given Boom Torque**
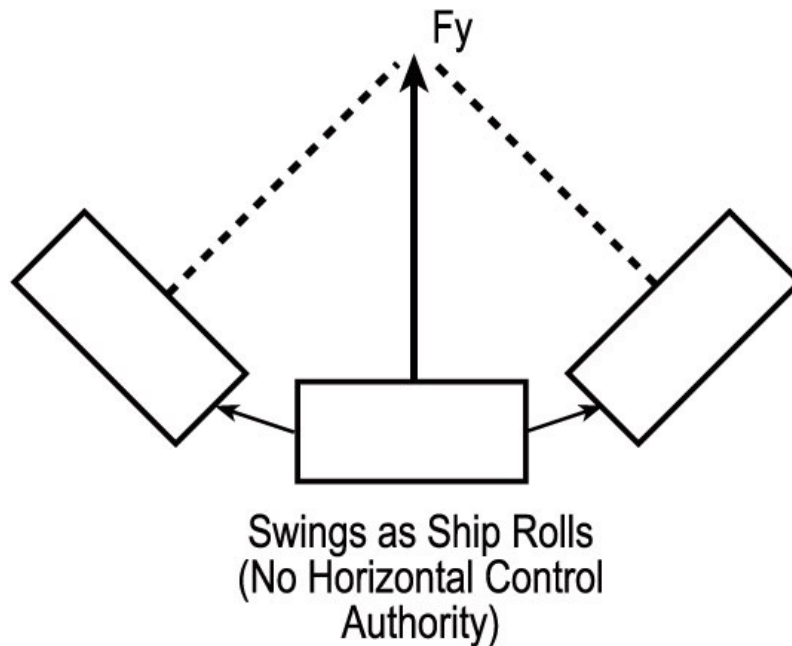- **Use Technology with Growth Potential**

Array Configuration

- **AutoLog Array provides horizontal and rotational control authority for the first time.**

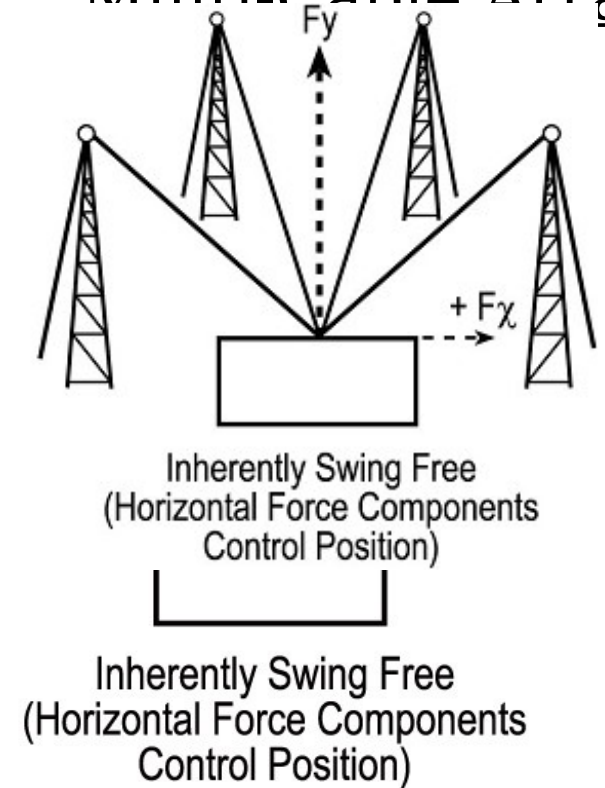- **AutoLog Array Remains Swing-Free Even During Power Loss.**

Penn State / Seic

Array Concept Avoids Problems With
6 DOF Effects (i.e. from Roll Pitch Yaw Heave Surge & Sway)

Single Vertical Cable

Multi-Cable Array

Fy

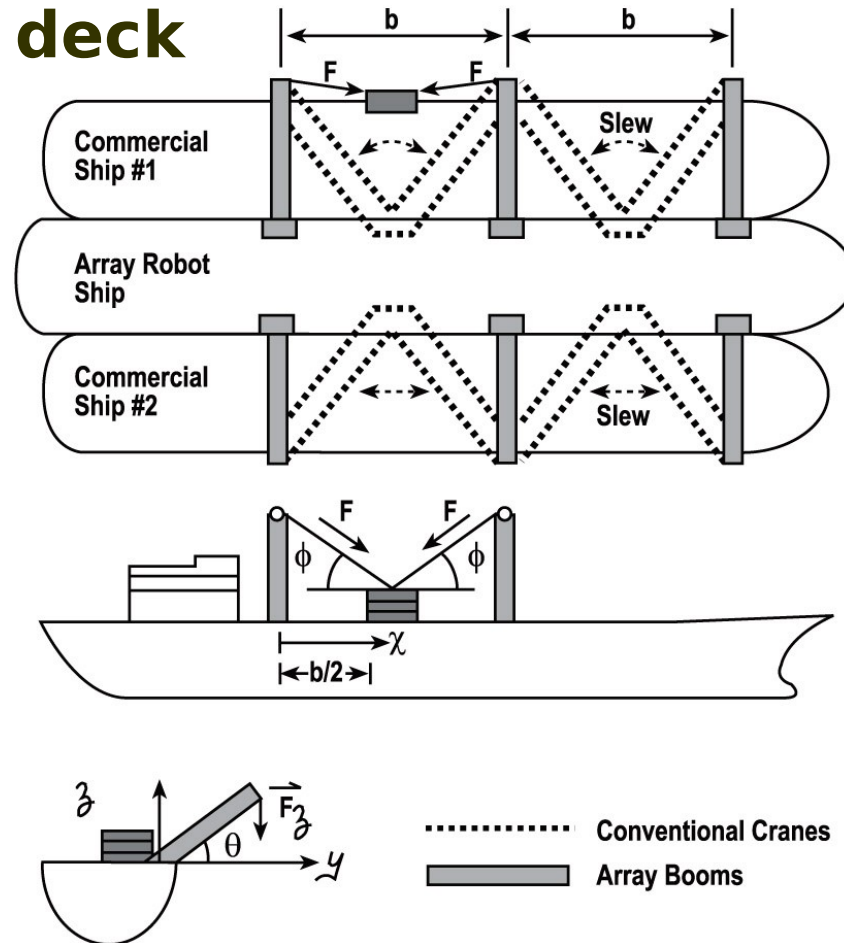Fy

+ Fx

Swings as Ship Rolls
(No Horizontal Control
Authority)

Inherently Swing Free
(Horizontal Force Components
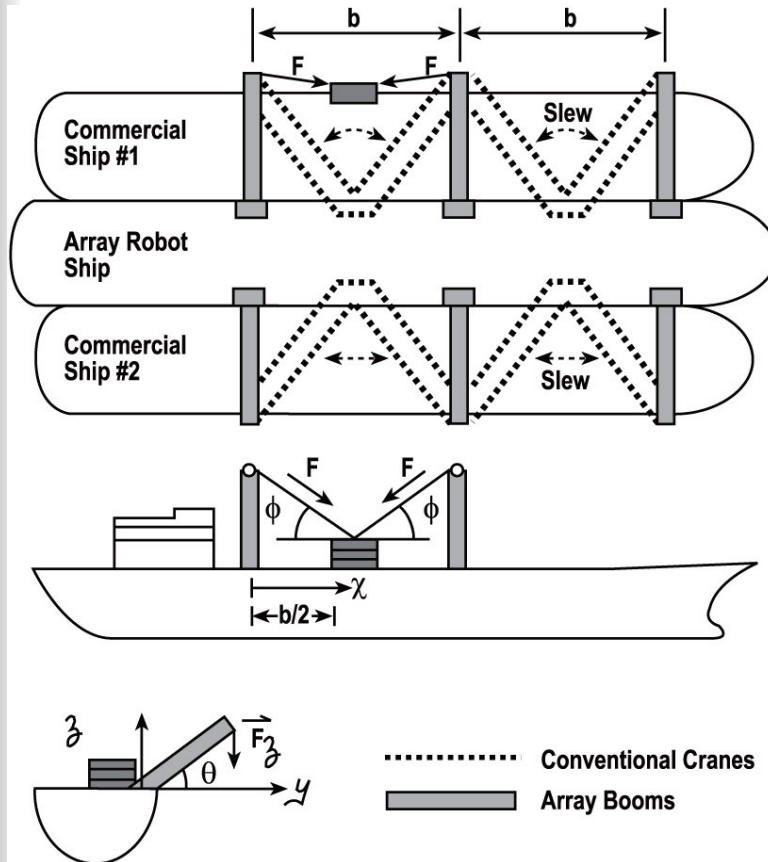Control Position)

Inherently Swing Free
(Horizontal Force Components
Control Position)

Sea Basing with AutoLog

- **AutoLog ship-to-ship transfer involves reduced forces and moments to the ship deck**

Commercial Ship #1

Array Robot Ship

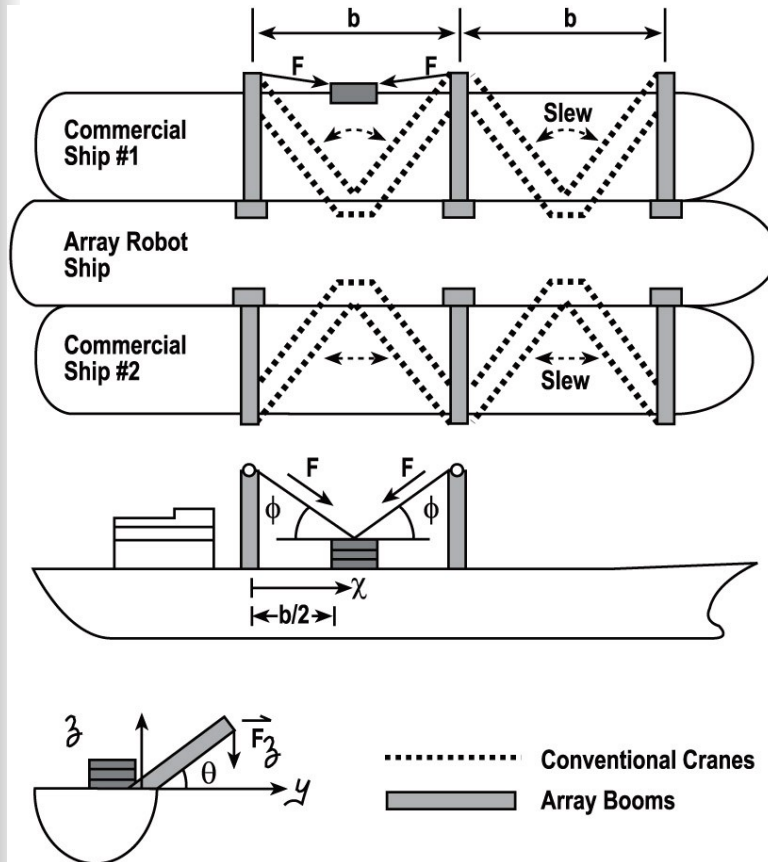Commercial Ship #2

Slew

Slew

Conventional Cranes

Array Booms

Array Concept Minimizes & Distributes Structural Loads and Moments

- **AutoLog Array has n + 2 fixed booms that distribute load. Only the cables and load move.**

- **AutoLog backstays can be used given fixed booms of an array.**

- **Conventional Cranes, by contrast, must pass all loads and moments through a rotating thruster bearing (dotted lines). No back stays are possible.**

Array Concept Maximizes Reach & Workspace Area For a Given Boom Torque

Commercial Ship #1

Array Robot Ship

Commercial Ship #2

Slew

Slew

F   F

b   b

F   F

φ   φ

b/2   χ

Conventional Cranes

Array Booms

- **Resultant Conventional Moment Torque =**

W * (a^2+(b/2)^2)^1/2

- **Resultant Array Moment Torque =**

W * (a^2+h^2)^1/2 * (cos^2Theta +

cos^2Phi*Sin^2Theta)^1/2

Conclusion: Array always has less Resultant moment (e.g. 80%)

Array Concept Uses Technology with High Future Growth Potential

- **Automated Laser and Vision Assisted Spreader Bar--for capturing containers and landing them smoothly on a moving platform.**
- **Automated "Put that ... there" Human interface--with option to manually drive containers in any direction or rotation as desired.**

SEICOR CHARLESTON

AutoLog Container/Cargo Transfer System

AutoLog Offloading w/ Other Ships, Lighters a

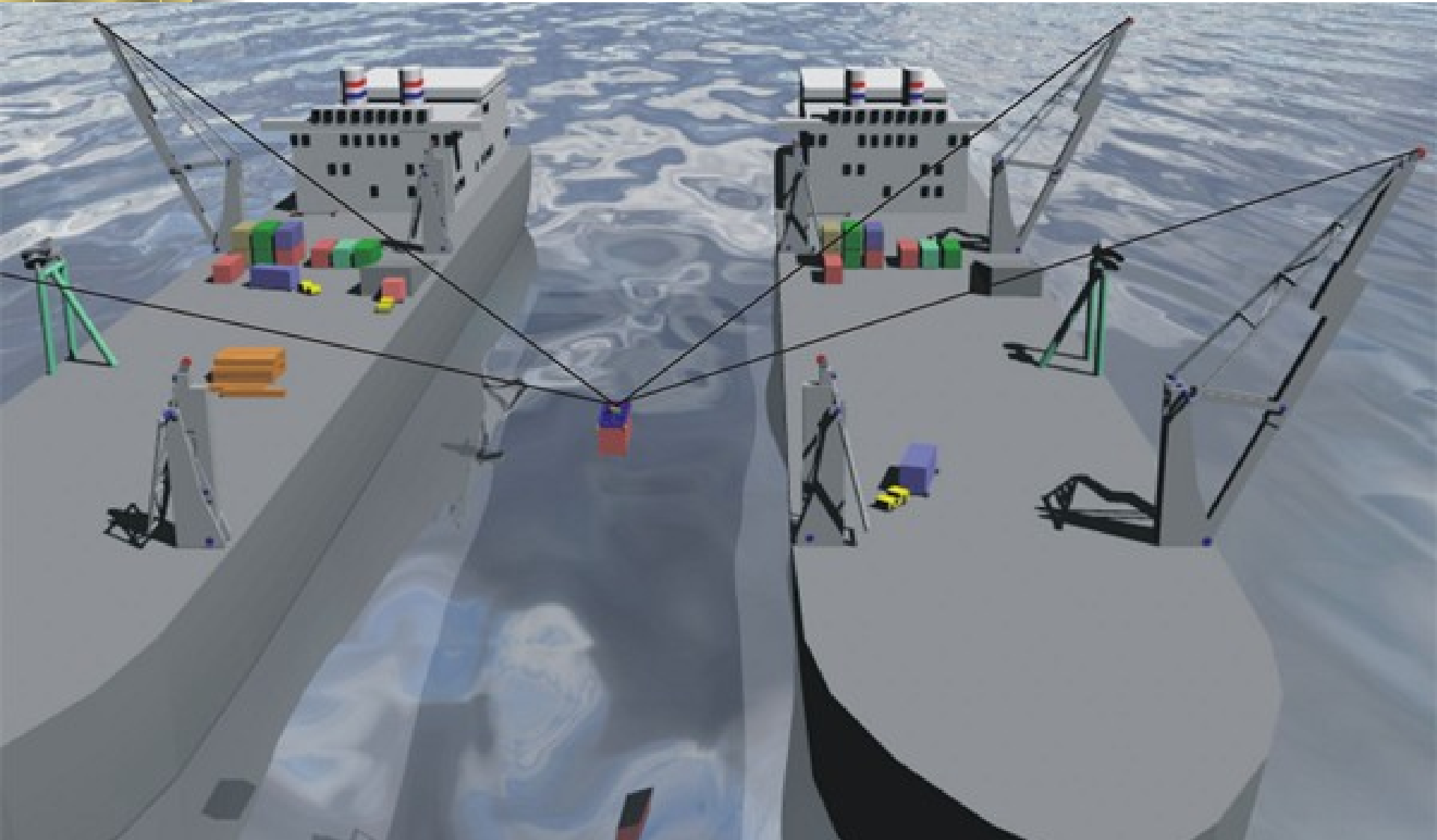# Outdoor Site for: GPS; Natural Light Vision; Laser Guided Landing Tests etc.

- **Power (110V & 220V)**
- **Internet (5 ports)**

Penn State / Seic

Offloading by RC Helicopter (Smaller

- **A live remote control helicopter test was performed for the integrated concept of offloading both vertically by air as well as to lighters at sea.**

Penn State / Seic

Sea Based Logistics
AutoLog Underway

Hybrid UnRep

- **Marvin Miller (NSWC-PHD) Would Like AutoLog with Heavy UnRep**
- **Start With: High Throughput AutoLog Feed To Current UnRep**
- **Keep Current Spacing Between Ships**
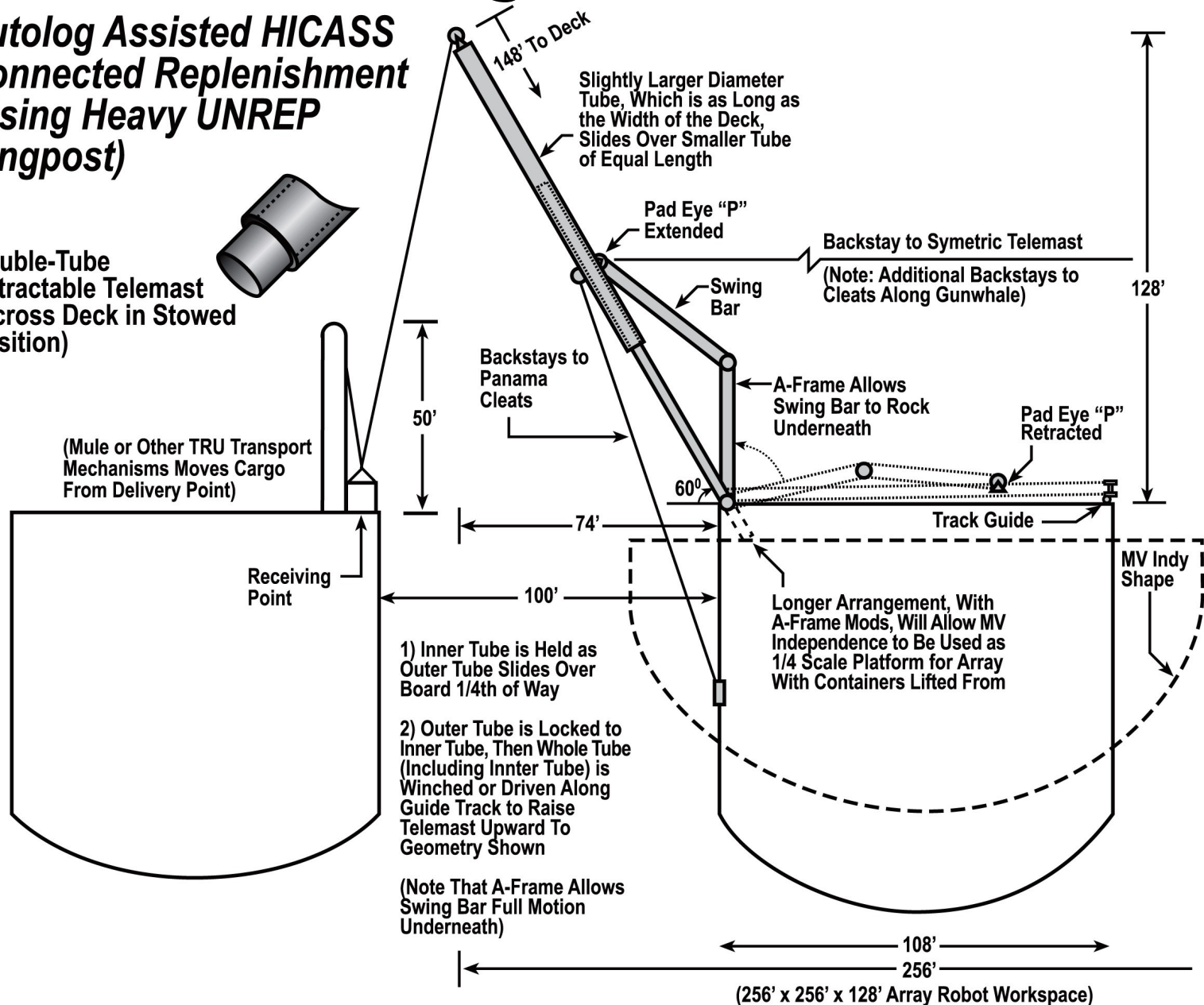- **Keep High Line System with Out- Haul and Back-Haul**

Future Heavy-Lift Assist

- **Later: Multi-Platform Kinematics, Dynamics and Controls for accommodating relative ship motion.**

- **AutoLog Cables carry the extra weight while transferring full containers underway .**

- **Carrier Wave/Differential GPS measures relative platform motions.**

Autolog Assisted HICASS Connected Replenishment (Using Heavy UNREP Kingpost)

148' To Deck

Slightly Larger Diameter Tube, Which is as Long as the Width of the Deck, Slides Over Smaller Tube of Equal Length

Pad Eye "P" Extended

Backstay to Symetric Telemast
(Note: Additional Backstays to Cleats Along Gunwhale)

128'

Double-Tube Retractable Telemast (Across Deck in Stowed Position)

Swing Bar

Backstays to Panama Cleats

A-Frame Allows Swing Bar to Rock Underneath

Pad Eye "P" Retracted

50'

(Mule or Other TRU Transport Mechanisms Moves Cargo From Delivery Point)

60°

Track Guide

Receiving Point

74'

MV Indy Shape

100'

Longer Arrangement, With A-Frame Mods, Will Allow MV Independence to Be Used as 1/4 Scale Platform for Array With Containers Lifted From

1) Inner Tube is Held as Outer Tube Slides Over Board 1/4th of Way

2) Outer Tube is Locked to Inner Tube, Then Whole Tube (Including Innter Tube) is Winched or Driven Along Guide Track to Raise Telemast Upward To Geometry Shown

(Note That A-Frame Allows Swing Bar Full Motion Underneath)

108'

256'

(256' x 256' x 128' Array Robot Workspace)

5

Full Container Transfer < 20 Ton Kingpost Cable

Autolog for Platform to Platform (UNREP/CONREP):

(50,000 lb Sea State 4, Treat as Four Cable System as for Two Cables Treated as One Cable)

($\triangle$ Horizontal Far Cables & Assume: Lizard Line)

At Point A Just Before Drop Off:

$$\varepsilon F_y = T_1 \cos \theta_1 + T_2 \cos \theta_2 - ma = 0$$

$a = 1.5g$
$w = 50,000 \text{ lb}$
$\theta_1 = .21 \text{ rad}$
$\theta_2 = .25 \text{ rad}$
$T_1 = T_2$ (For this Case of $\theta_1 \approx \theta_2$)

$$2T_1 = \frac{1.5 W}{\cos(\theta_1)}$$

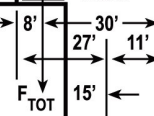$$T_1 = \frac{1.5 W}{2 \cos(.21 \text{ rad})} = \frac{1.5 (50K)}{2 \cos(13°)} = 38,500 \text{ lbs}$$ Including Dynamic Loading

$\theta_1 = \tan^{-1} \frac{8}{38}$
$= .21 \text{ rad}$
$= 11.9°$

$\theta_2 = \tan^{-1}\left(\frac{30}{116}\right) = .25 \text{ rad}$
$= 14.5°$
$128-12 = 116$

King Post

$50-12 = 38$

AT Drop Point:
$T_1 = 38,500 \text{ lb}$

Point A (Drop Point)

$T_1 \quad T_2$

Point B

$8'$ $30'$
$27'$ $11'$

F_{TOT} $15'$

Offload Fairlead

At Point B, 15 Feet Overboard:

$$\varepsilon F_x = T_2 \sin \theta_2 - T_1 \sin \theta_1 = 0$$

$\theta_1 = \tan^{-1}\left(\frac{27}{38}\right)$ (∇ Assume Lizard Line Balances Load of Far Cables)
$= 35.4°$

$\theta_2 = \tan^{-1}\left(\frac{11}{116}\right)$
$= 5.4°$

$$T_1 = \frac{T_2 \sin \theta_2}{\sin \theta_1} = \frac{.0944 \, T_2}{.579} = .16 \, T_2$$

$$\varepsilon F_y = T_1 \cos \theta_1 + T_2 \cos \theta_2 = 75,000 \text{ lb}$$

$$.815 \, T_1 + .99 \, T_2 = 75,000 \text{ lb}$$

$$T_2 = \frac{75,000 \text{ lb} - .815 \, T_1}{.99}$$

$$T_1 = .16 \, T_2 = .16 \left(\frac{75,000 - .815 \, T_1}{.99}\right)$$

$$T_1 (1 + .132) = 12,100$$

AT 15' Overboard
$T_1 = 10,700 \text{ lb}$

$74'$

$100'$

Heavy UnRep Trade-Offs

- **Can increase ship spacing if Kingpost (Ram Tensioner) shares higher loads with AutoLog Array.**

- **Can increase throughput if AutoLog feeds High-Line system during light cargo transfers.**
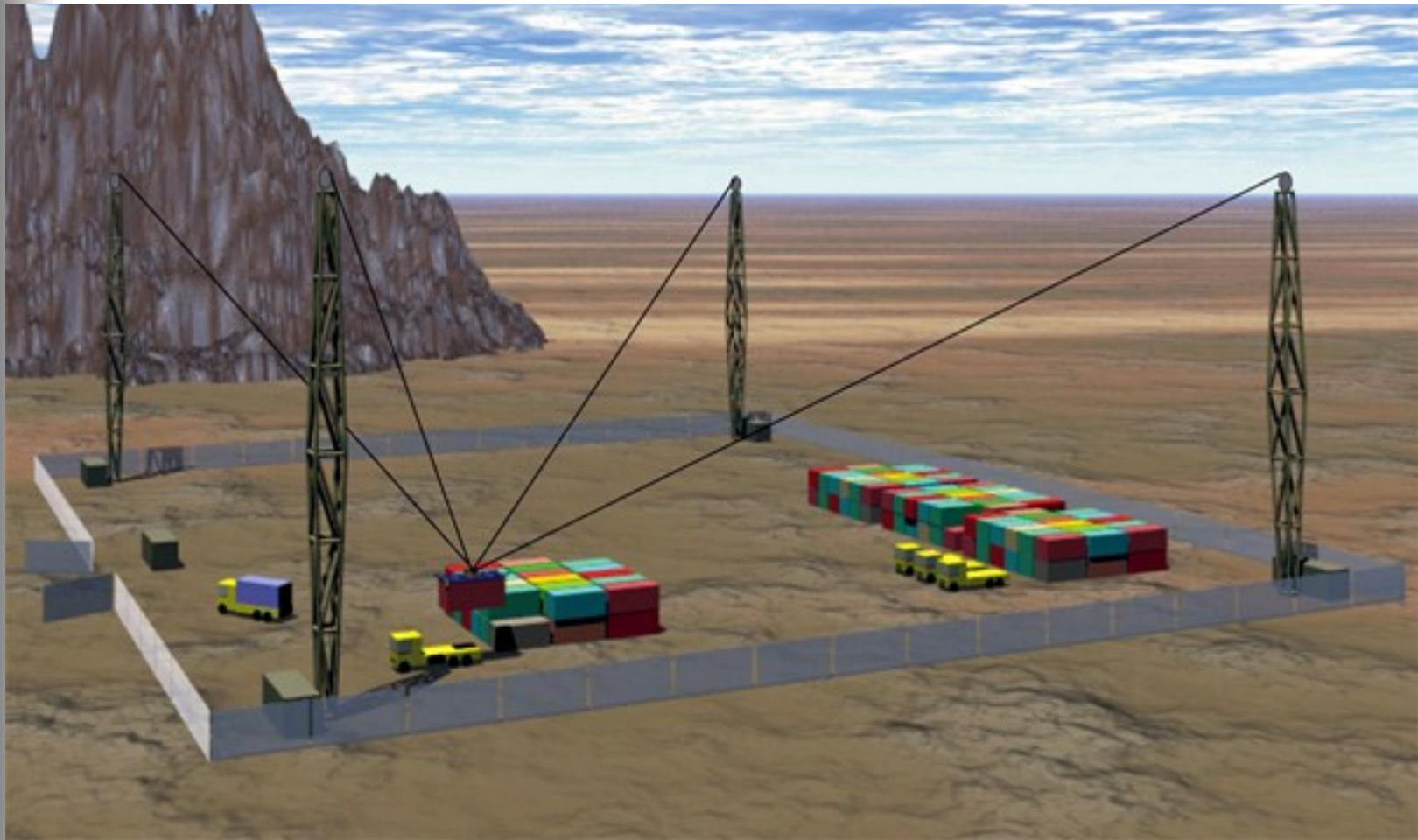
Additional Future Applications

- **New Class of Cable Array Robotic System**

- **Many Opportunities for Stabilization in Crane Related Navy Tasks.**
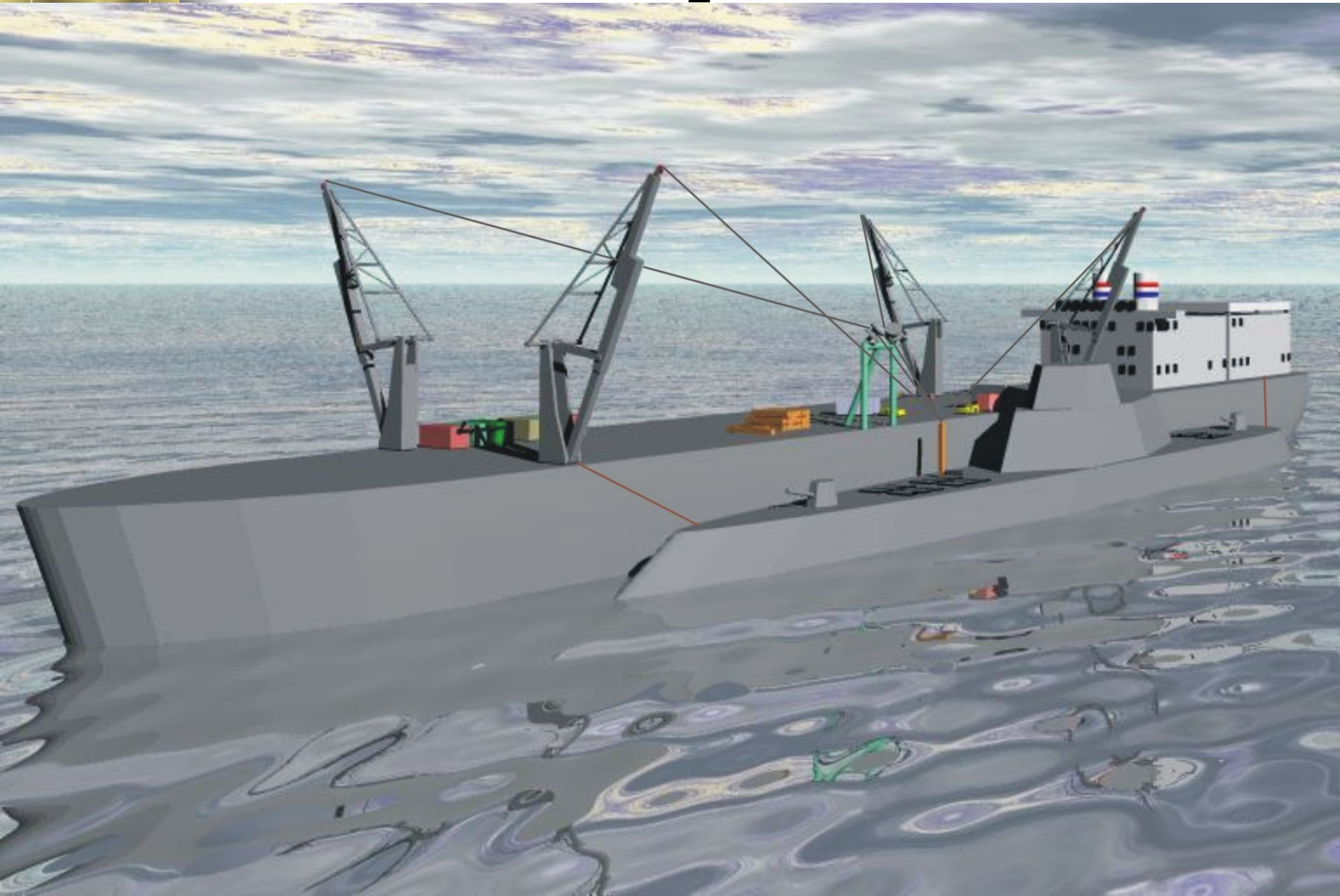
- **Three Examples and Many More:**

AutoLog Beach Marshalling Yard
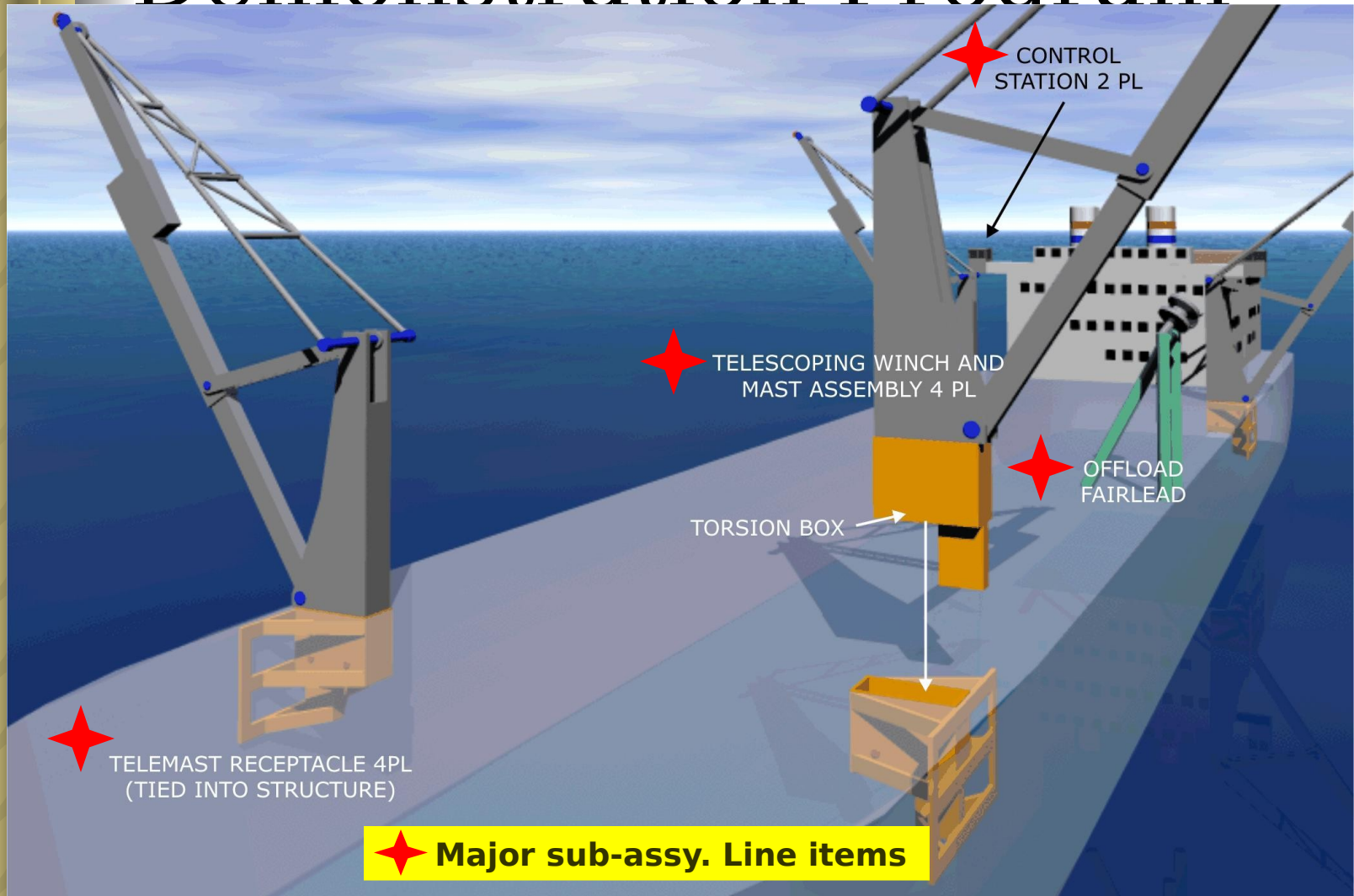
AutoLog Field/Depot

Missile Replenishment

AutoLog Subsystem Details

- **Deployable Fixed TeleMasts**
- **Active Spreader Bar**
- **GUI Human Interface to AutoLog**
- **Messenger Spreader for Hull Lifts**
- **Single Wrap Winch Drums**

Proof of Concept Demonstration Program

CONTROL STATION 2 PL

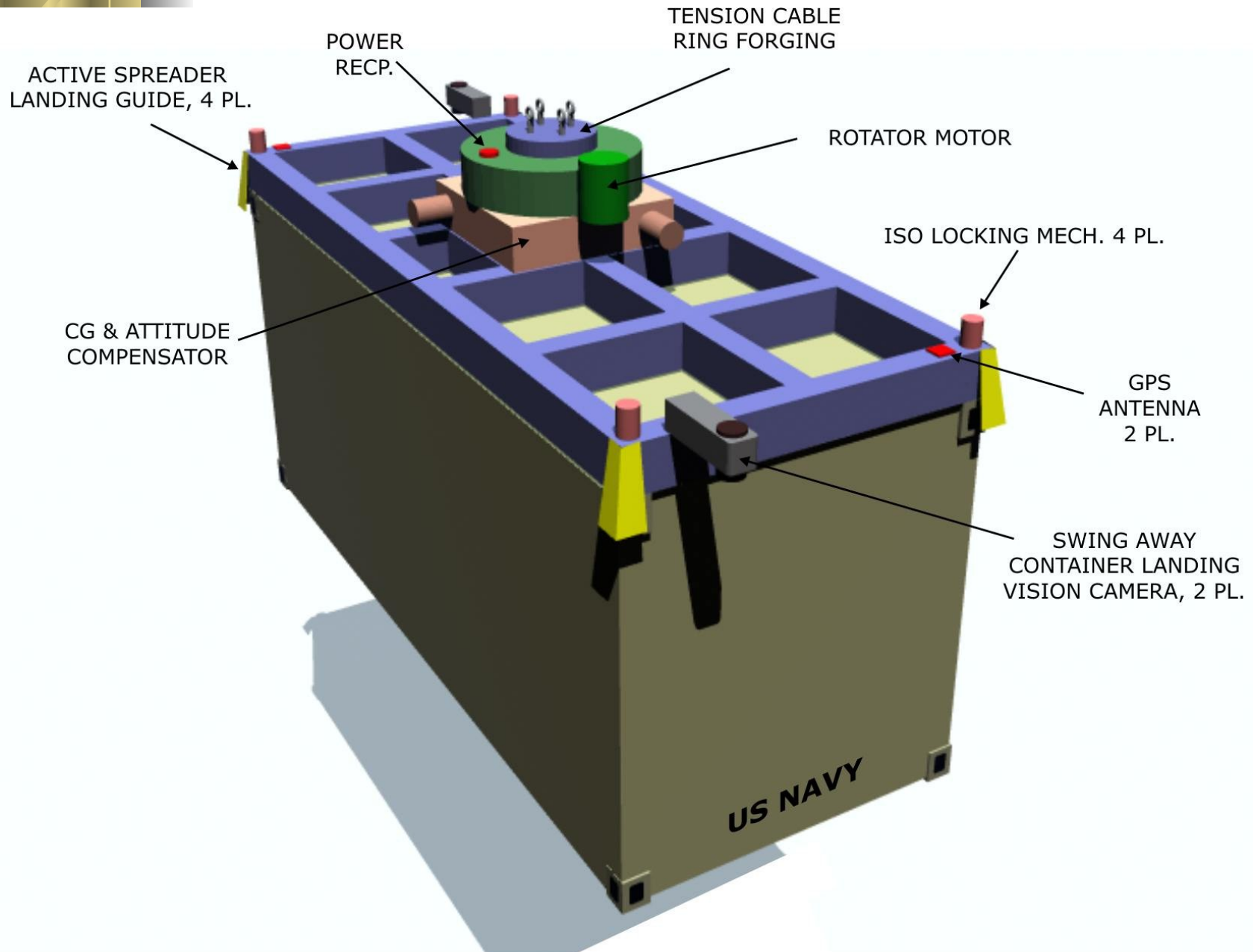TELESCOPING WINCH AND MAST ASSEMBLY 4 PL

OFFLOAD FAIRLEAD

TORSION BOX

TELEMAST RECEPTACLE 4PL (TIED INTO STRUCTURE)

⭐ Major sub-assy. Line items

Retractable Fixed TeleMast

Active Spreader

TENSION CABLE RING FORGING

POWER RECP.

ACTIVE SPREADER LANDING GUIDE, 4 PL.

ROTATOR MOTOR

ISO LOCKING MECH. 4 PL.

CG & ATTITUDE COMPENSATOR

GPS ANTENNA 2 PL.

SWING AWAY CONTAINER LANDING VISION CAMERA, 2 PL.

US NAVY

PSU Laser Guided Landing Test

- **¼ Scale Container**

- **Suspended from Telemasts on Crane Rails**

- **Viewed From Ship Bridge (2nd Floor Lab Window)**

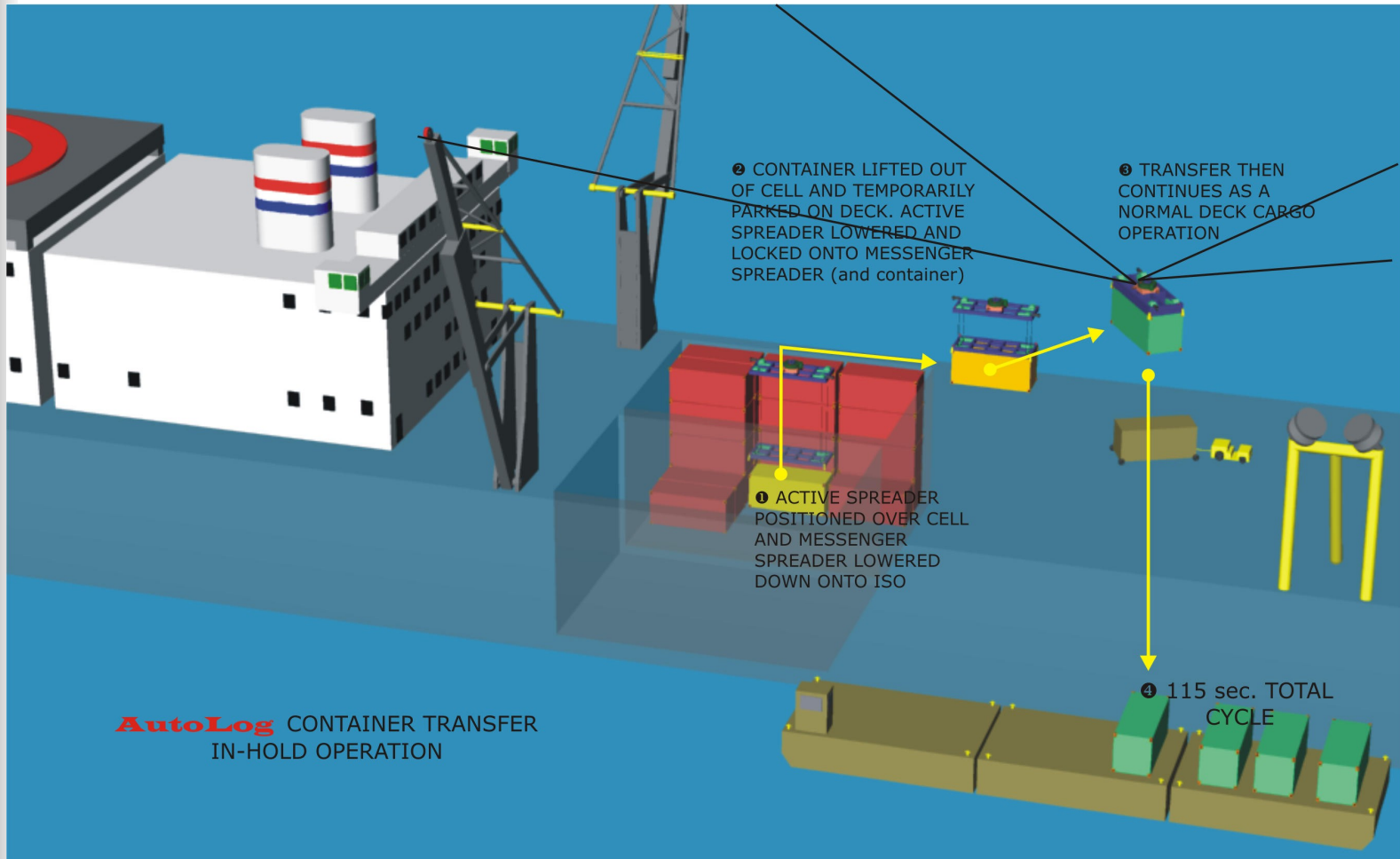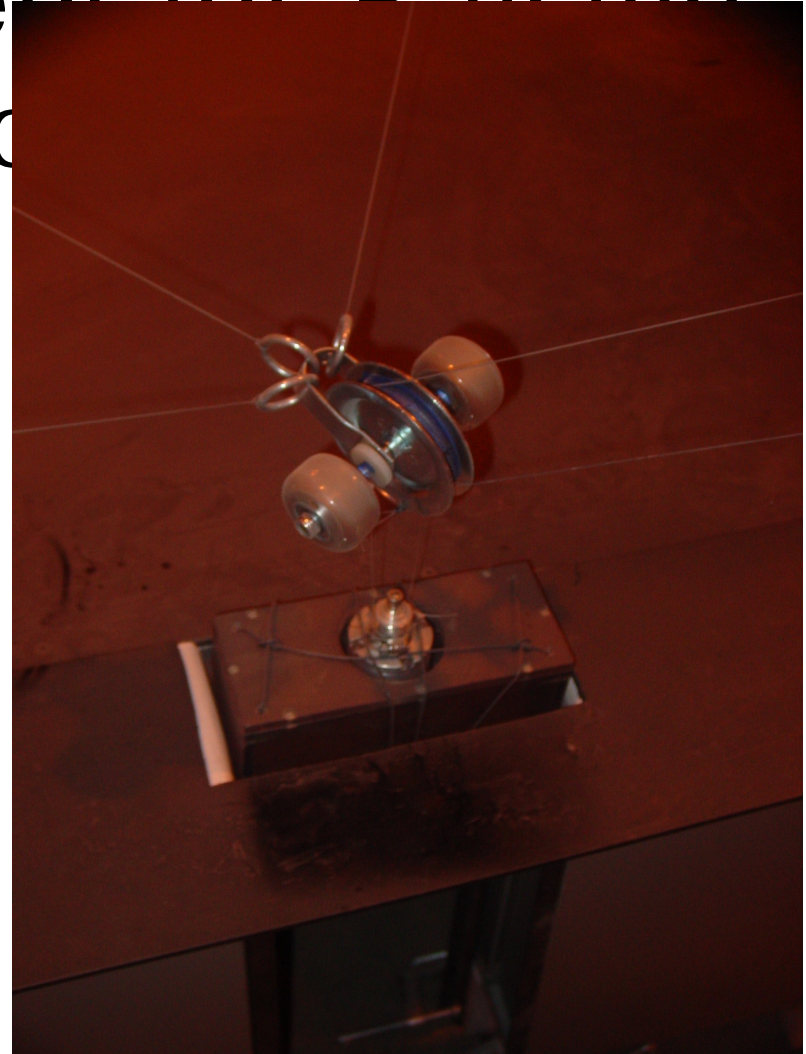# Lasers For Guided Landings

Lands Flat ; Lands Adjacent
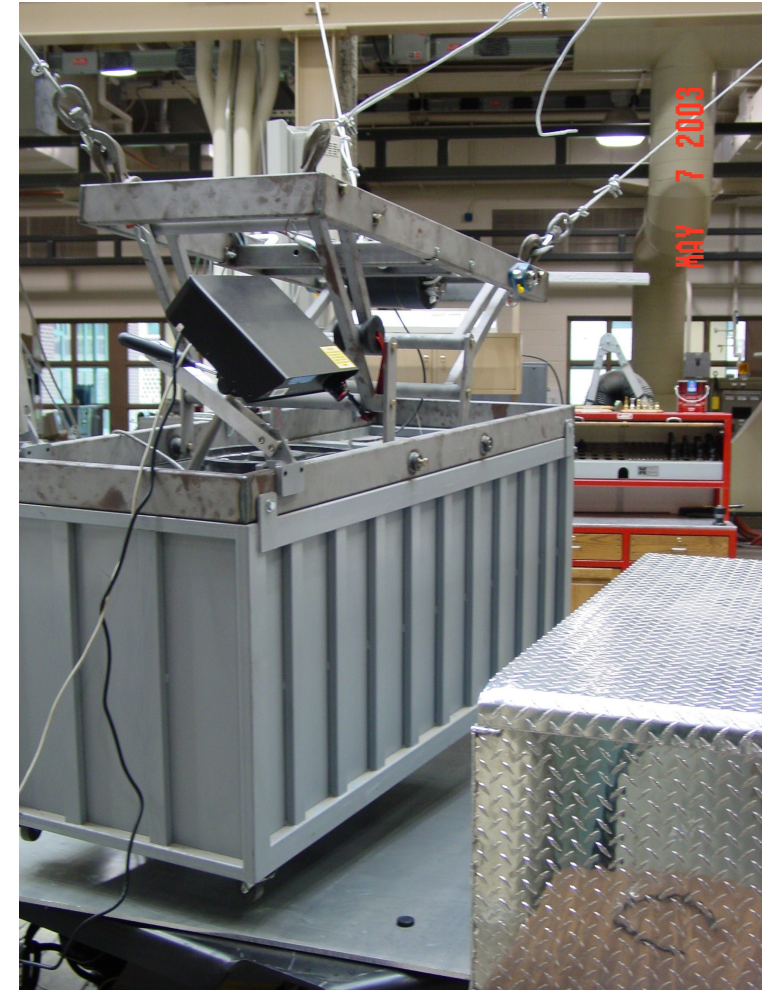
Container Retrieval From Hold

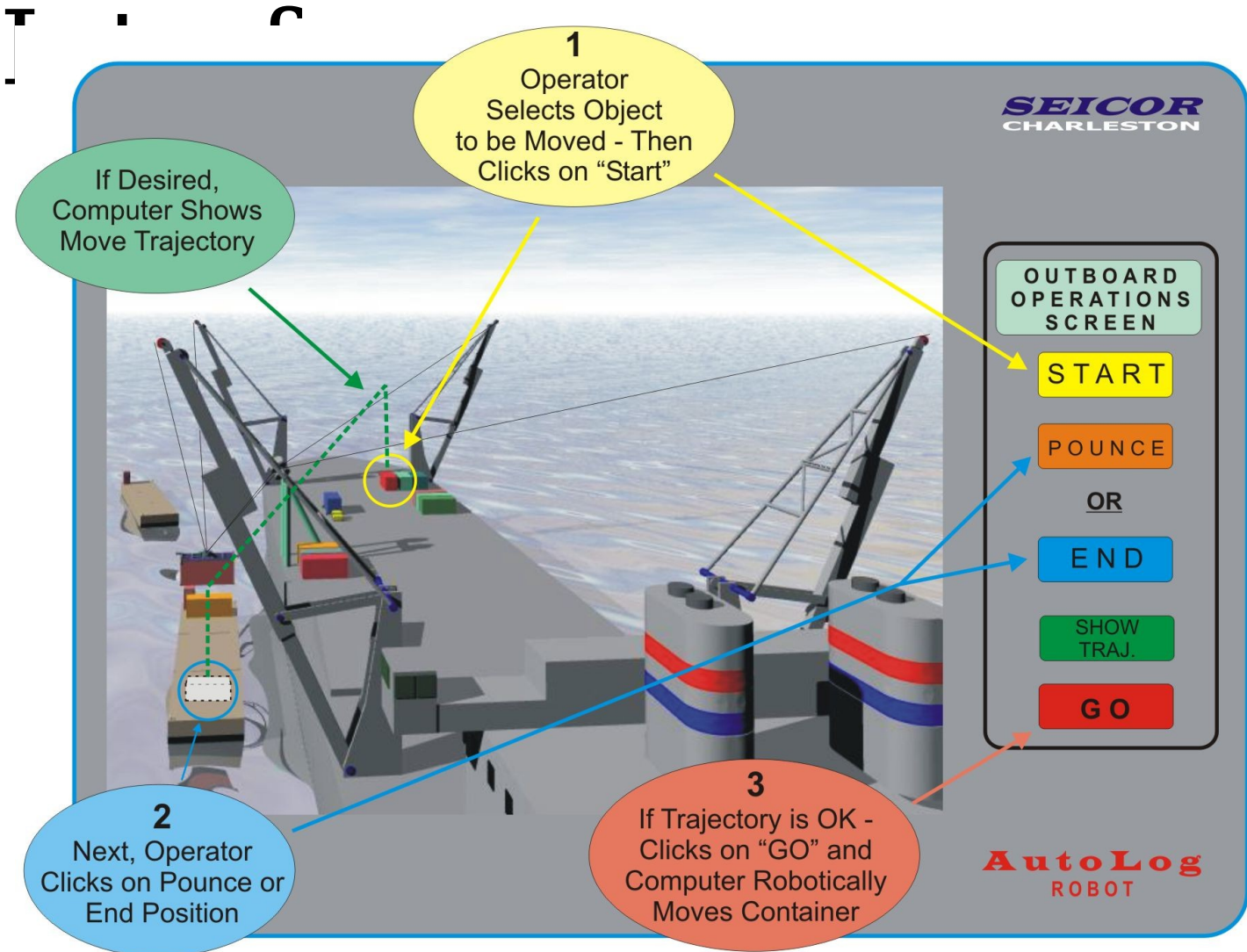❷ CONTAINER LIFTED OUT OF CELL AND TEMPORARILY PARKED ON DECK. ACTIVE SPREADER LOWERED AND LOCKED ONTO MESSENGER SPREADER (and container)

❸ TRANSFER THEN CONTINUES AS A NORMAL DECK CARGO OPERATION

❶ ACTIVE SPREADER POSITIONED OVER CELL AND MESSENGER SPREADER LOWERED DOWN ONTO ISO

AutoLog CONTAINER TRANSFER IN-HOLD OPERATION

❹ 115 sec. TOTAL CYCLE

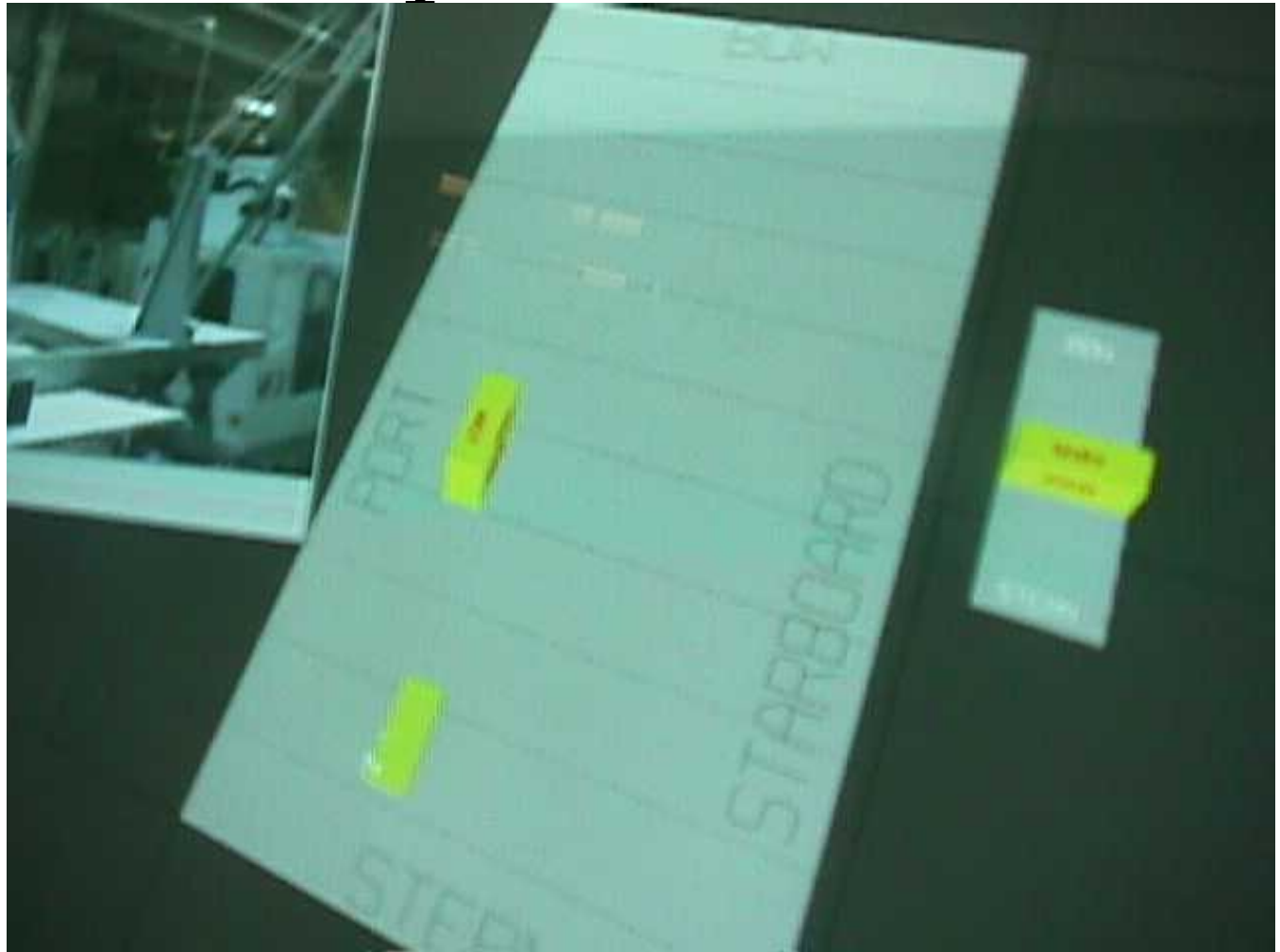# Model Test of Stationary Rotator Concept for Raising Containers From Hold

- **Pivot point stays fixed above cell.**
- **Pulley rotates in place.**
- **Main winch cable doubles back in "Fan Belt" mode.**
- **Spreader lowers down from secondary cables wound on axel.**

Point-And-Direct Interface

1 Operator Selects Object to be Moved - Then Clicks on "Start"

If Desired, Computer Shows Move Trajectory

2 Next, Operator Clicks on Pounce or End Position

3 If Trajectory is OK - Clicks on "GO" and Computer Robotically Moves Container

SEICOR CHARLESTON

OUTBOARD OPERATIONS SCREEN

START

POUNCE

OR

END

SHOW TRAJ.

GO

AutoLog ROBOT
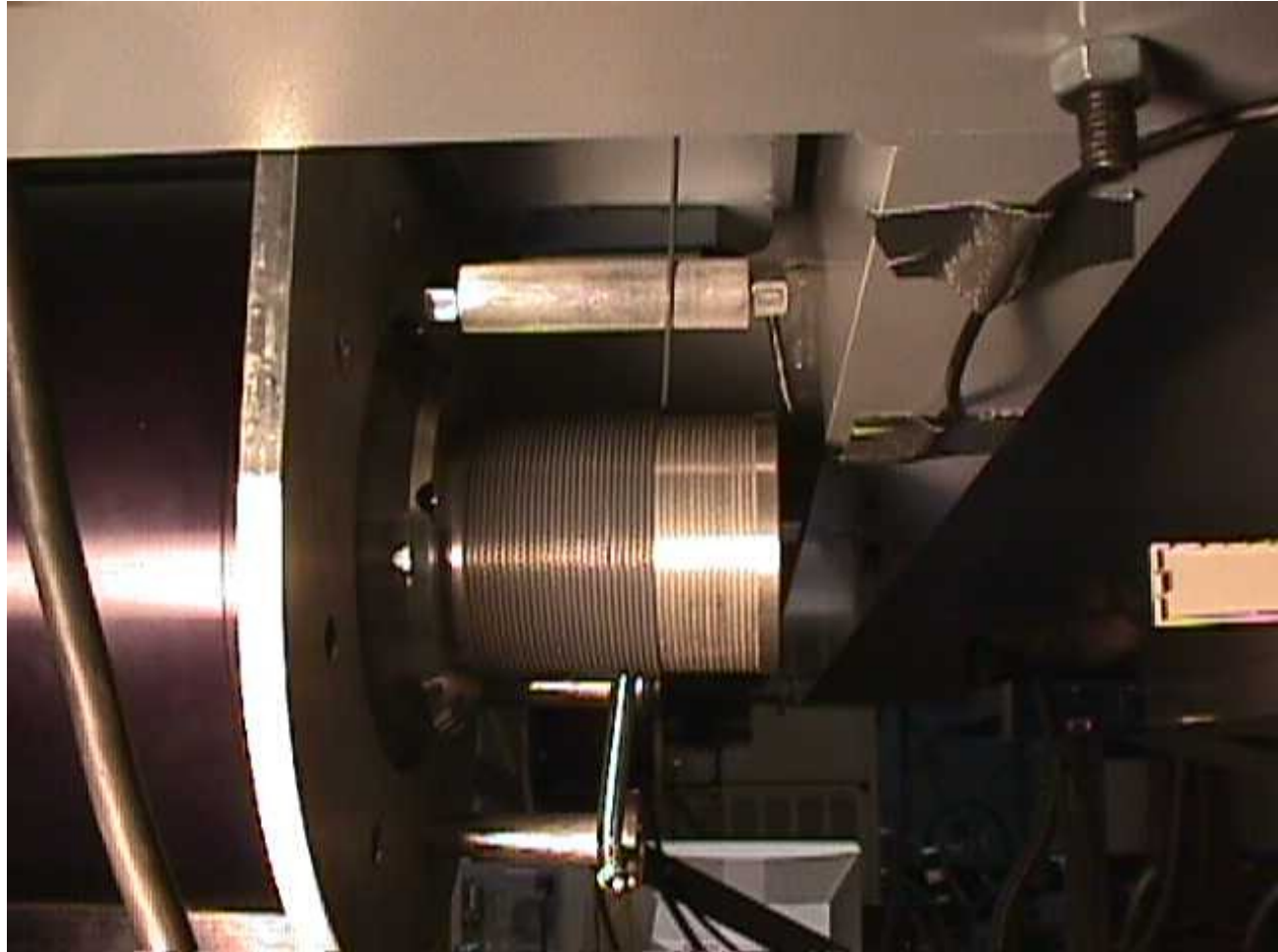
Point-And-Direct GUI with Graphical Preview

[Show Video Of Pointing and Directing Operations From GUI InterFace]
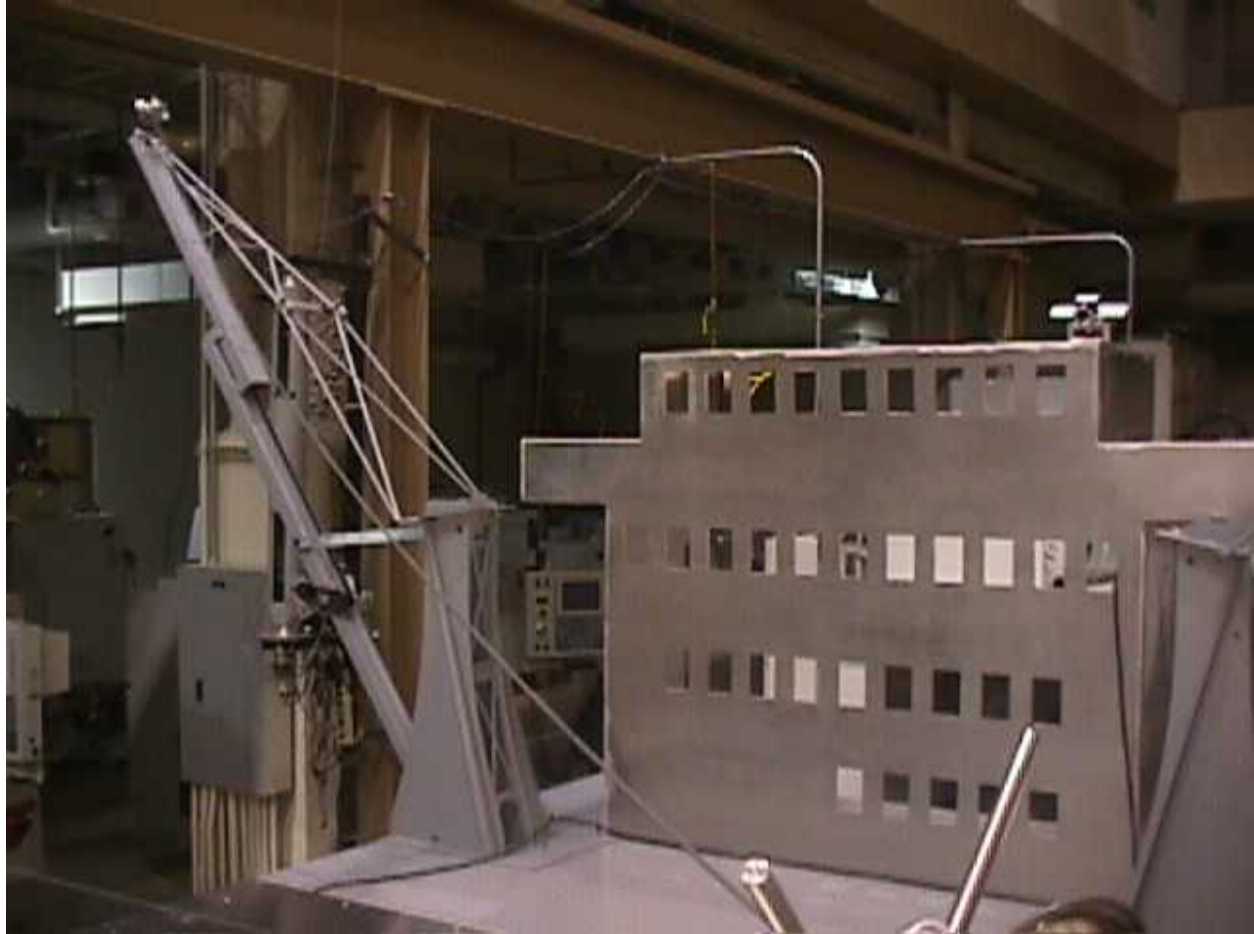
Point Positioning; Yaw Control
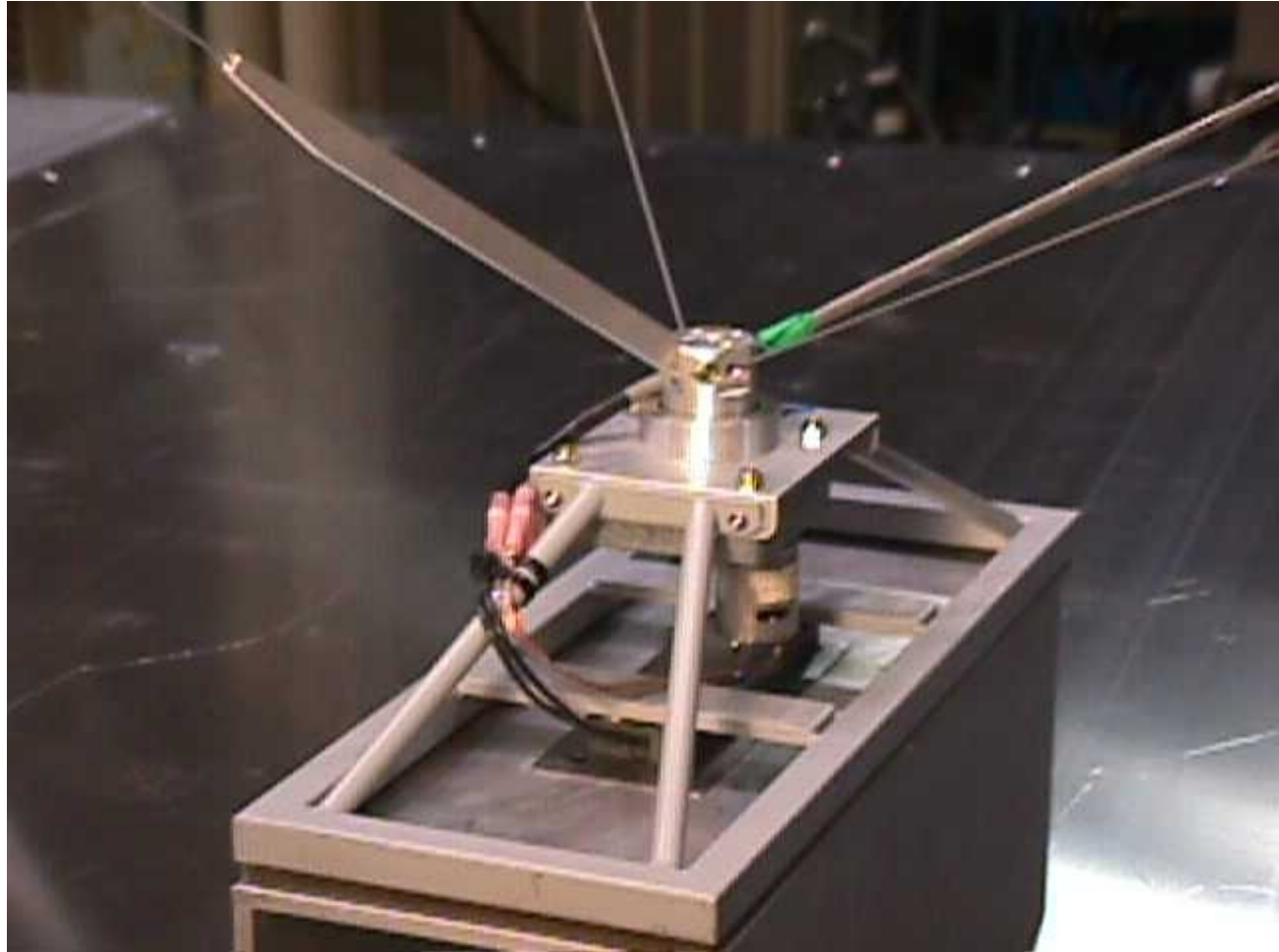
Single Layer Wrap On Drum

Higher Sea State Performance

Bridge Cab Eases Collaboration
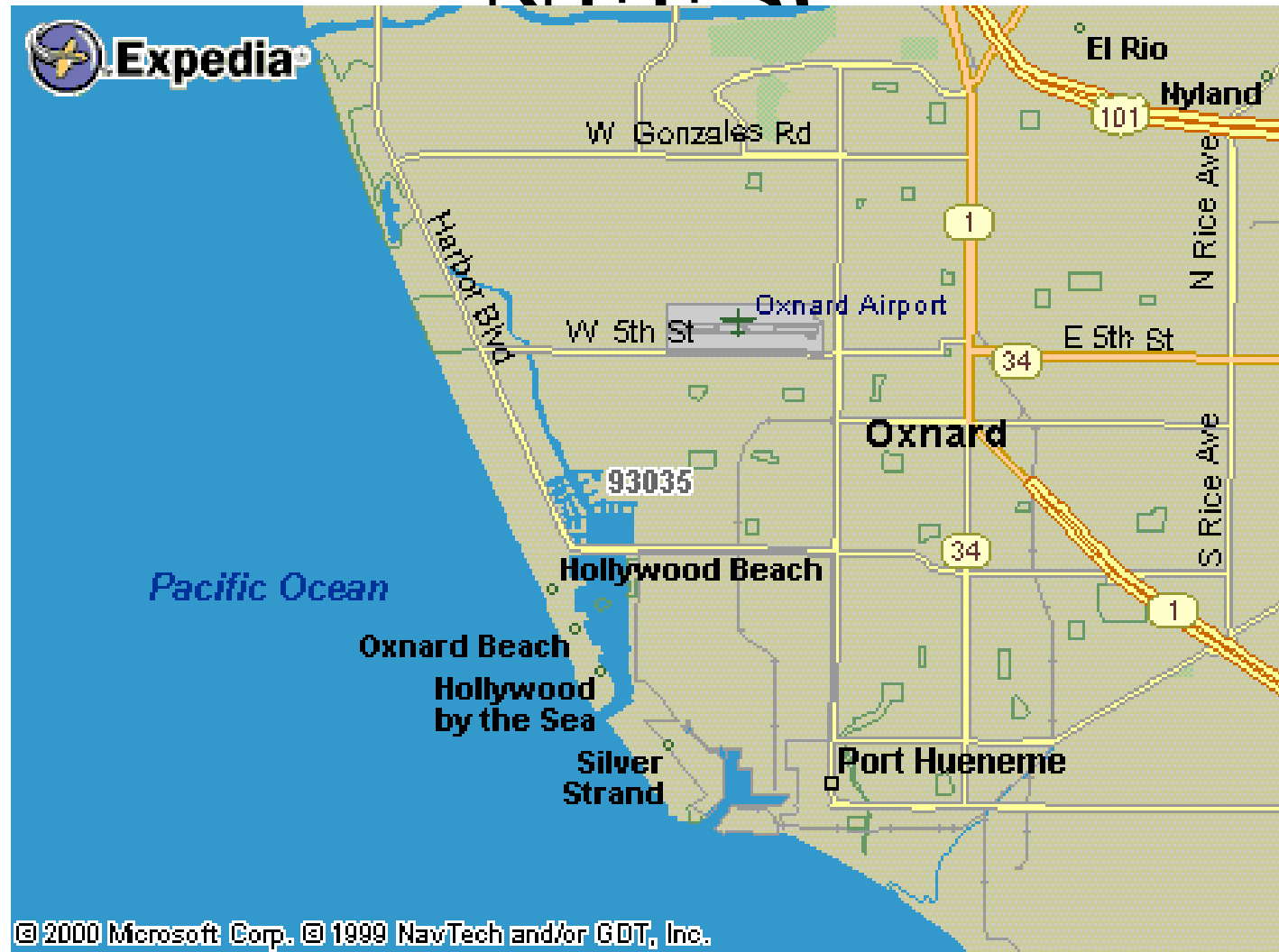
Robust Machine Vision Allows For Variations

Lab Vision Platform

Penn State / Seic   49

Mission Need Statement (MNS)

- **Section 5b1 says: MPF(F) must perform its <u>offload mission in sea state 3</u>, perform essential ship functions in sea state 5 and survive sea state 8.**

Contracted Test Site at NEESC

AutoLog Container/Cargo Transfer System